INVENTOR: DiFoggio
TITLE: A Method and Apparatus for Downhole Quantification...
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EXPRESS NO.: EV369817905US DOCKET NO.: 584-30872-US
SHEET 1 OF 6

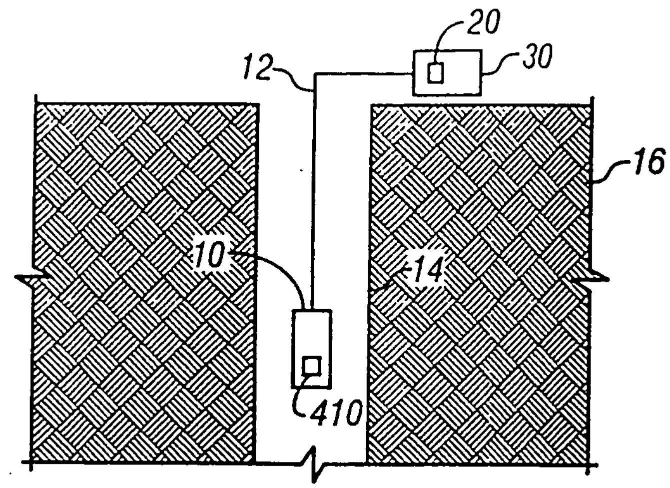

FIG. 1

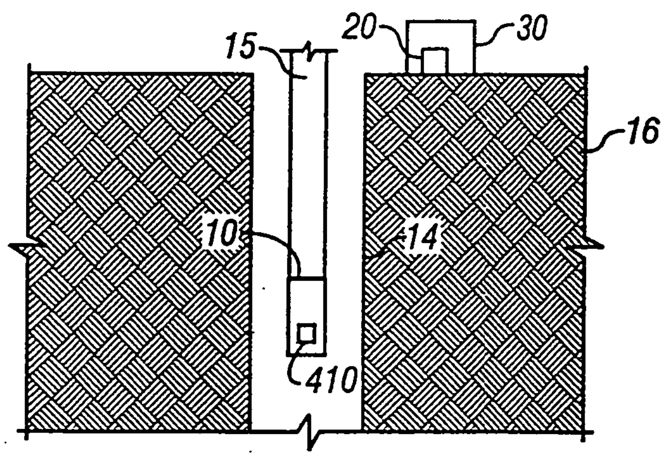

FIG. 2

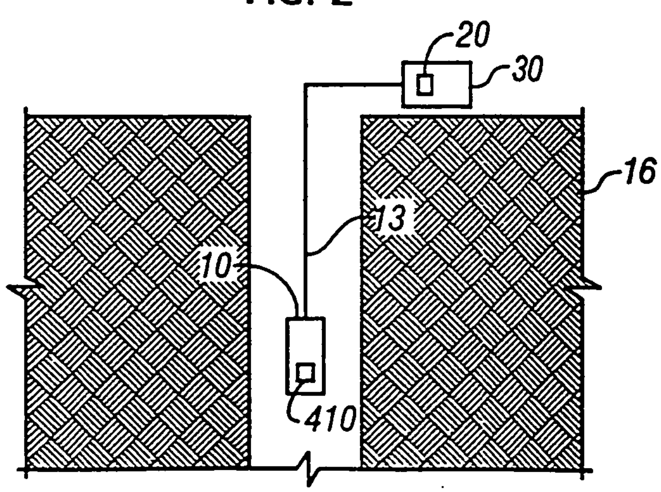

FIG. 3

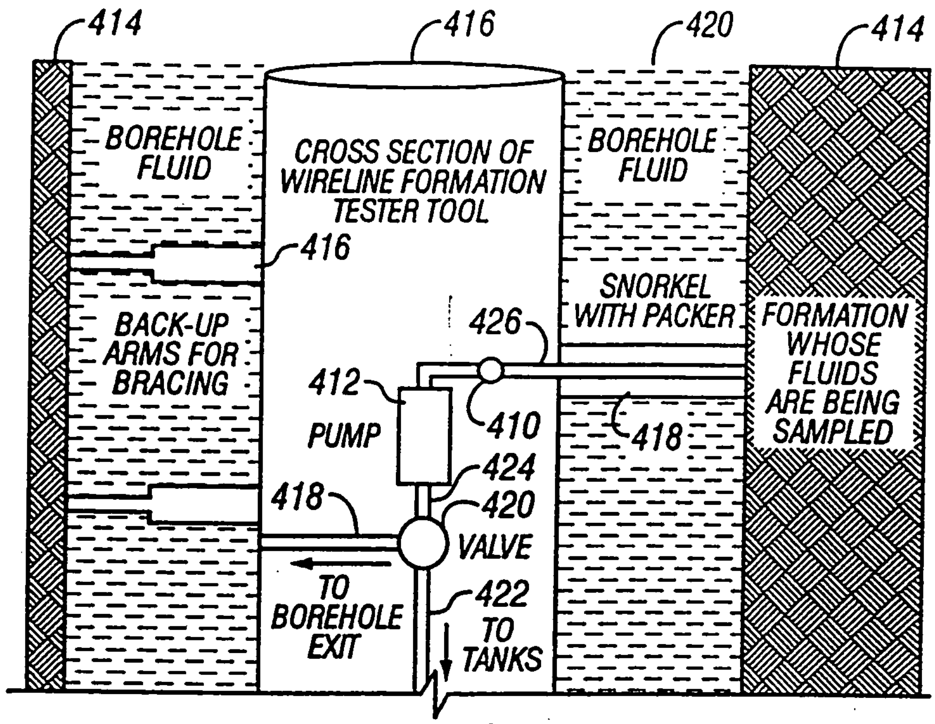
414
416
420
414
BOREHOLE FLUID
CROSS SECTION OF WIRELINE FORMATION TESTER TOOL
BOREHOLE FLUID
416
SNORKEL WITH PACKER
BACK-UP ARMS FOR BRACING
426
FORMATION WHOSE FLUIDS ARE BEING SAMPLED
412
PUMP
410
418
424
418
420
VALVE
TO BOREHOLE EXIT
422
TO TANKS

FIG. 4

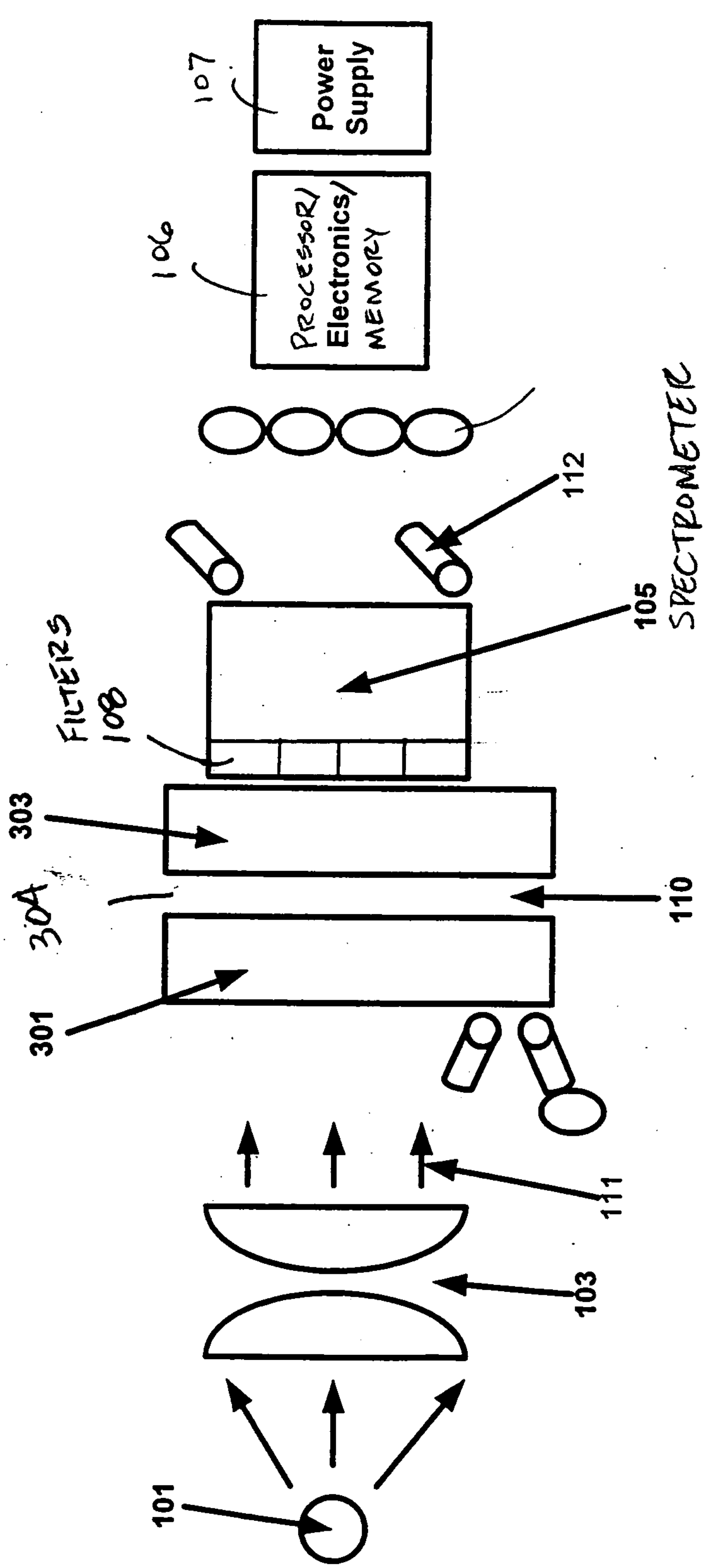
107
Power Supply
106
PROCESSOR/ Electronics/ MEMORY
112
105
SPECTROMETER
FILTERS 108
303
304
110
301
111
103
101

FIG. 5

FIG. 6

Equations Correlating Weight Fraction Methane in Mixtures of Crude Oil and Methane to Optical Absorbance and Temperature

Methane Weight Fraction = **METHWTF = B0 + B1 * Var1 + B2 * Var2 + B3 * Var3 + B4 * Var4 ...**

SQ70-82 = SQUARE(Absorbance_at_1670_nm - Absorbance_at_1682_nm)
SRSA1670 = SQRT(Absorbance_at_1670_nm)
SRSA1682 = SQRT(Absorbance_at_1682_nm)
TEMP_C = Temperature in Degrees Centrigrade
TEMP_SQR = Square of Temperature in Degrees C

Regression Summary for Dependent Variable: **METHWTF**
R= .98093203 R^2= .96222765 Adjusted R^2= .96151158
F(4,211)=1343.8 p<0.0000 Std.Error of estimate: .04992

		B	
		0.06514	= B0 = Intercept
Var1 =	SQ70_82	11.1756	= B1
Var2 =	TEMP_C	0.00087	= B2
Var3 =	SRSA1682	-2.66167	= B3
Var4 =	SRSA1670	2.63245	= B4

Regression Summary for Dependent Variable: **METHWTF**
R= .98190316 R^2= .96413381 Adjusted R^2= .96327986
F(5,210)=1129.0 p<0.0000 Std.Error of estimate: .04876

		B	
		0.03143	= B0 = Intercept
Var1 =	SRSA1670	2.53111	= B1
Var2 =	SRSA1682	-2.55766	= B2
Var3 =	SQ70_82	11.9135	= B3
Var4 =	TEMP_C	0.0019	= B4
Var5 =	TEMP_SQR	-6.2E-06	= B5

Equation for Density of Methane [g/cc] as a Function of Pressure and Temperature
from 100 - 30,000 psia and 75 - 200 C
is fitted by Adj. R^2= .99911359

	B	
	2.771E-03	= Intercept
P	2.480E-05	
P^2	-1.120E-09	for Pressure in psi
P^3	1.808E-14	
T^2	-1.308E-07	for Temperature in C
(P/T)	1.455E-03	
$(P/T)^2$	-4.922E-06	
$(P/T)^3$	5.934E-09	

Equation for Optical Absorbance per mm of Methane as Function of Density and Wavelength
at 11 nm FWHM, Center λ range of 1668-1684 nm,
for 100-30,000 psia, and 75 - 200 C,
is fitted by Adj. R^2= .94145159

	B	
	-19.9061	= Intercept
Methane Density	0.7747	for Density in g/cc
WaveNumber/1000	3.3326	

where, WaveNumber ≡ 10 000 000 / λ [nm]

Equations Relating Gas Oil Ratio, GOR, to Weight Fraction of Methane, f_M, and Stock Tank Density, ρ_O, of Oil

1 bbl = 0.159 m^3=5.615 cu ft=42 U.S. gal
1 Standard Cubic Foot (SCF) of Methane Gas at 14.7 psia & 60°F is 0.042358 lbs = 19.21327 grams.
Density of Methane at 60 F and 14.7 psia is 0.0006787 gr/cc = 0.042358 lbm/ft^3.
Letting V = Volume, W = Weight, ρ = Density, and using **subscripts M for Methane and O for Oil**,
GOR ≡ $V_{Methane}$ [SCF] / V_{Oil} [bbls] = $\{ W_M / (19.21 \text{ g/SCF}) \} / \{ (W_O / \rho_O)(1 \text{ bbl} / 158\,983 \text{ cc}) \}$
Letting f_M = Weight Fraction of Methane,
GOR = $8274.62\, \rho_O / (1 / f_M - 1)$
$f_M \equiv W_M / (W_M + W_O) = \rho_M V_M / (\rho_M V_M + \rho_O V_O)$ so $W_O = W_M / (1 / f_M - 1)$ which substitutes into above.
$f_M = 1 / (1 + 8274.62 * \rho_O / GOR)$ where W_G and W_O are in grams, ρ_O is in g/cc, and f_M = Wt. Frac. of Methane

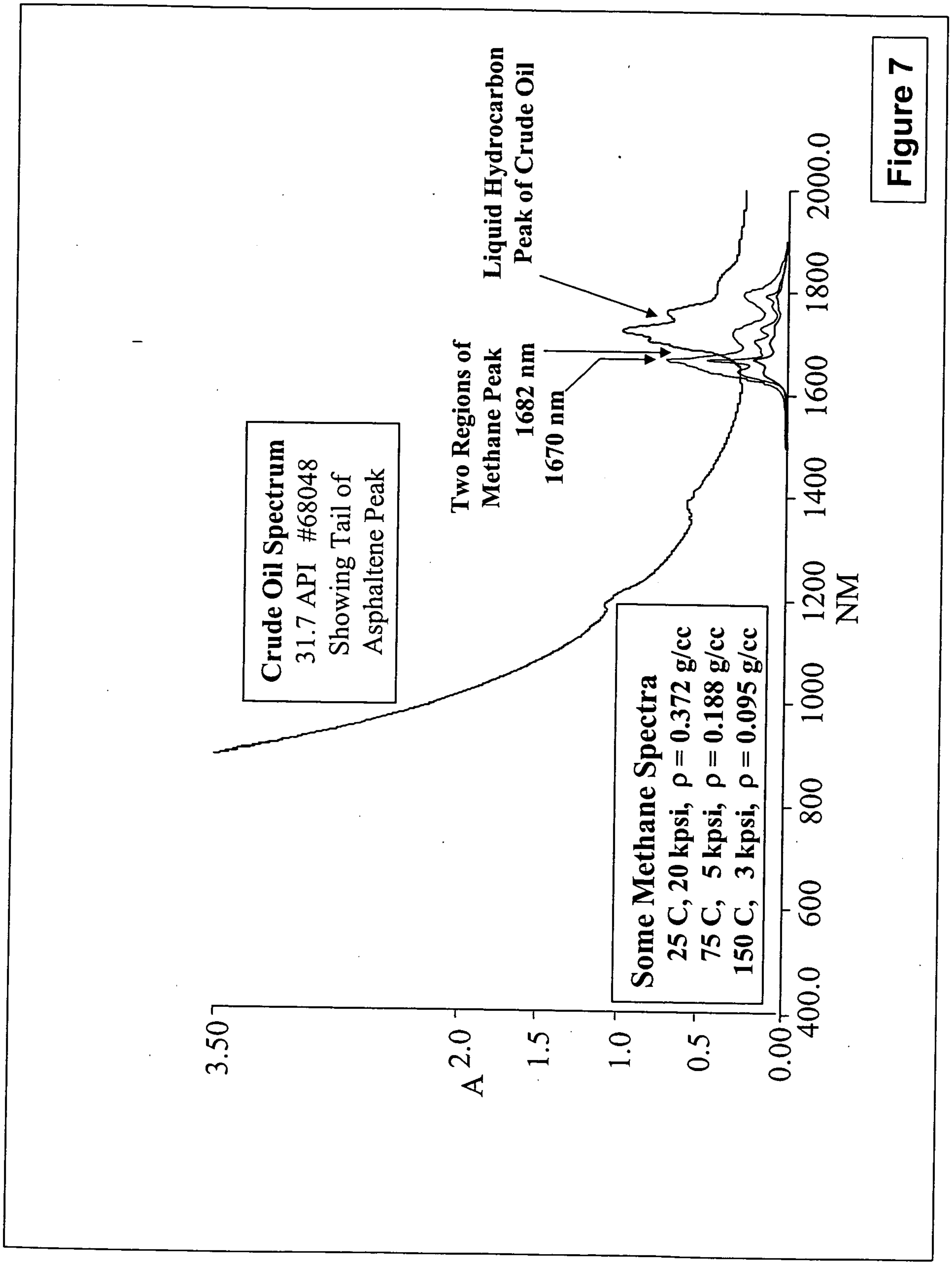
Crude Oil Spectrum
31.7 API #68048
Showing Tail of
Asphaltene Peak
Two Regions of
Methane Peak
1682 nm
1670 nm
Liquid Hydrocarbon
Peak of Crude Oil
Some Methane Spectra
25 C, 20 kpsi, ρ = 0.372 g/cc
75 C, 5 kpsi, ρ = 0.188 g/cc
150 C, 3 kpsi, ρ = 0.095 g/cc
A
3.50
2.0
1.5
1.0
0.5
0.00
400.0
600
800
1000
1200
1400
1600
1800
2000.0
NM

Figure 7

Prepare training set of high-resolution absorption spectra of synthetic mixtures of methane and dead crude oils. — 810

↓

Degrade high-resolution spectra to 11 nm FWHM corresponding to best available high-temperature filters. — 812

↓

Determine best correlating center wavelengths (1670 nm and 1682 nm) to weight fraction of methane in crude oils. — 814

↓

Determine correlation equations that use best correlating wavelengths and/or temperature and/or pressure. — 816

↓

Obtain a first absorbance of a downhole fluid at a first wavelength region (1670 nm) associated with a methane peak. — 818

↓

Obtain a 2nd absorbance of a downhole fluid at a 2nd wavelength region (1682 nm) associated with a methane peak. — 820

↓

Using derived correlation equation, determine weight fraction of methane and GOR for the downhole fluid. — 822

Figure 8